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Neutrino-Mass Hierarchy and The Roles of Radioactive Nuclear Reactions in Explosive Nucleosynthesis of Supernovae, Collapsars and Mergers

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The detection of gravitational waves from the binary neutron star merger GW170817 and supernova (SN) neutrinos from SN1987A opened a new era of multi-messenger astronomy and astrophysics, and we are able to understand the cosmic chemical evolution with these events to seek for the origin and evolution of atomic nuclei. A keen scientific objective is to understand how the strong, electromagnetic and weak interactions play the role in SN explosion dynamics and nucleosynthesis. Firstly, we will propose a new astrophysical method of supernova nucleosynthesis to constrain still unknown neutrino mass hierarchy [1]. The flavor conversion effects due to the collective quantum effect as well as MSW effect are found to play the critical roles in neutrino-process nucleosynthesis at high density. We also propose that the isotopic ratios among Lithium, Boron, Lanthanum, etc. in SN presolar-grains provide a clear signature of mass hierarchy dependence [1]. Secondly, we will discuss the roles of radioactive ion-beam (RIB) reactions, where we find that $C11(a,p)N14$ and several others strongly affect explosive nucleosynthesis of Lithium and Boron isotopes [2]. We have recently found that the i- and s-processes could occur in the r-process site of collapsar nucleosynthesis [3], and we make a list of important unmeasured RIB reactions on light-to-heavy mass nuclei [4]. Finally, we will clarify how the different candidate astrophysical sites for the heavy element production, i.e. magneto-hydrodynamic-jet SNe, collapsars, and binary neutron-star mergers, have contributed to the enrichment of heavy elements in cosmic evolution [5].

- [1] X. Yao, T. Kajino, Y. Luo, et al., *Astrophys. J.* 980 (2025), 247(21pp).
- [2] X. Yao, Y. Luo, T. Kajino, et al., *Chinese Physics C* (2025), to be published.
- [3] Z. He, T. Kajino, M. Kusakabe, et al., *Astrophys. J. Lett.* 966 (2024), L37.
- [4] Z. He, T. Kajino, Y. Luo, et al., (2025), to be published.
- [5] Y. Yamazaki, Z. He, T. Kajino, et al., *Astrophys. J.* 933 (2022), 112.

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